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USAF Strategy for Aging Aircraft Subsystem Research and Development

William C. Kinzig
ASC/ENFA
2530 Loop Road West
Wright-Patterson AFB, Ohio 45433-7101
USA

SUMMARY

Like many other nations today, the United States Air Force (USAF) is retaining their existing aircraft longer than planned. It is estimated that the current average age of aircraft in the USAF inventory today is 22 years old. By 2005, 75% of the USAF inventory will be over 20 years old. As the age of our fleet continues to rise, aircraft mission capable rates degrade and there is a potential for increased risk to safety of flight should the aircraft not be properly maintained. Maintenance data indicates that air vehicle subsystems are one of the largest contributors to aircraft downtime due to in-service failures. Fortunately aircraft typically are not lost due to the subsystem failures. However, if one is not careful, this aspect can tend to foster an attitude that we should accept these failure rates. What this approach fails to recognize is that we no longer have the budget or the number of available aircraft to support this level of maintenance. The purpose of this paper is to discuss aging aircraft concerns found in air vehicle subsystems and the approach that the USAF is using to alleviate these concerns.

BACKGROUND

Philosophically, the USAF aging aircraft program began in the late 1950's following an in-flight structural wing failure of a B-47 aircraft [1]. As a result, the USAF developed the Aircraft Structural Integrity Program (ASIP) [2]. The ASIP [3] is a disciplined engineering process that defines all of the tasks necessary to ensure the structural integrity of the air vehicle airframes. ASIP is a cradle-to-grave process and has become the basis for our aging aircraft programs.

ASIP has evolved over the last 40 years into a very effective and widely accepted process that is used extensively throughout the USAF. There is an Air Force Policy Directive [4] that requires implementation of the ASIP on all the USAF aircraft programs. The process has been very effective and we have not lost a USAF aircraft due to an inherent structural failure for over ten years [5].

As a result of the success of the ASIP, a similar integrity process has been established for the other elements of the air vehicle. In the 1970's, the Engine Structural Integrity Program (ENSIP) [6] was founded, and in the 1980's, the Avionic Integrity Program (AVIP) [7] and the Mechanical Equipment and Subsystem Program (MECSIP) [8] were also founded. ENSIP, AVIP and MECSIP are all patterned after the highly successful ASIP and all have similar type of tasks.

Even though the MECSIP has been in existence for about 13 years, the F-22 program was the first to implement it during the design/development phase. In 1995, due to the ever-increasing age of the USAF inventory, the Air Mobility Command became concerned with the future of their aging aircraft and initiated an Aging Aircraft Process Action Team (PAT). The purpose of the PAT

was to implement a disciplined engineering process for the sustainment of their fleet. The goal is to ensure safety, improve aircraft availability and assist in maintenance planning. Air vehicle subsystems were included in the process with the MECSIP being a key element for defining the overall disciplined engineering process. However, in reviewing the existing MECSIP MIL-HDBK-1798, it was concluded that the sustainment section of the handbook was lacking. Consequently, a team was formed to revise the MECSIP document and the document is in its final stages of coordination. The revised document should be released late this calendar year.

STRATEGY FOR AGING AIRCRAFT

J. Lincoln, Air Force Senior Leader for Aircraft Structural Integrity, described the strategy for using research and development to reduce maintenance costs as a six-step process [9]. The steps are:

1. Conduct surveys to determine problems
2. Identify solutions
3. Establish research and development roadmaps
4. Obtain management approval
5. Implement research and development
6. Transition technology to the operator

The major thrust of this paper is to discuss the results to date of Step 1 relative to aircraft subsystems – i.e. to report the findings of our surveys.

As Lincoln indicated [9], the USAF established an Aging Aircraft Technologies Team (AATT) to review the problems associated with our aging fleet and to make recommendations on how best to direct our research and development dollars. The team consists of members from the Engineering Directorate at the Aeronautical Systems Center, the Air Force Research Laboratory, and the Aging Aircraft Program Office. All three organizations are located at Wright-Patterson AFB, OH. The first survey was conducted in July through August of 1998 and addressed only structures. Additional surveys were conducted in June through December 1999 and August through September 2000. Both of these surveys were expanded to include air vehicle subsystems. A fourth survey is currently in progress and should be completed by 31 Oct 01.

The surveys consisted of visits to the three Air Logistics Centers responsible for the sustainment of the various USAF aircraft. Interviews were conducted with engineers and maintainers directly responsible for the integrity of the aircraft. Approximately 30 aging weapon systems were surveyed each year. In order to facilitate the review, a list of 13 questions relating to subsystems was submitted in advance. The questions were directed at identifying the problem areas, what actions were being taken to improve subsystem reliability, and where our development dollars could best be targeted to improve overall system safety and mission readiness. The systems reviewed included hydraulics, fuels, environmental control, landing gear, auxiliary power, flight controls, electrical power and wiring.

MAINTENANCE DRIVERS

Based on the survey of approximately thirty aircraft programs, the order of the "Top 10" maintenance drivers varied somewhat between aircraft but were very consistent between the two surveys conducted in 1999 and 2000. Based upon the qualitative results of the survey, the following subsystems in the order shown are estimated to be the leading maintenance drivers:

- a. Landing Gear - Landing Gear was near the top of many program lists. Leading problems involve cracks in the main and nose landing gear assemblies and attachment points (e.g.

braces, trunions and torque arms), poor component service life due to wear, inadequate lubrication provisions, tire chunking and wheel speed transducer failures. The Landing Gear Team for the USAF overhaul facility located at Hill AFB stated that approximately 80% of the landing gear structural failures are due to stress corrosion cracking.

- b. Flight Controls - The Flight Control System also appeared high on many program lists. The problems vary significantly between aircraft and include items such as wear and chafing of the control cables, actuator failures including rod end and servovalve failures, and inadequate lubrication provisions. Some of the actuator rod end failures were the result of corrosion.
- c. Wiring - Wiring is a major concern with our aging aircraft. Wiring failures are typically attributed to chafing, deterioration of the insulation and corrosion at the connectors. Deterioration of the insulation is frequently attributed to the use of the Kapton material. Several aircraft System Programs Offices have initiated or are planning large-scale replacement of their wiring systems. Both the Aging Aircraft Technologies Team and the Air Force Research Laboratory have engineers dedicated to resolving the wiring issues.
- d. Hydraulics - Even though many people view hydraulics as a mature technology, we still experience many problems with that system. Problems identified include tube chafing, fluid contamination, pump failures and hose failures. One problem recently noted on both an aging aircraft system as well as a new system under development involves chafing under clamps due to sand and dirt becoming lodged between the tube and the clamp liner. Both programs are exploring potential changes to eliminate the problem. The changes being considered include changes in liner material, changes in clamp design and the addition of a protective film around the tube itself.
- e. Fuels - Component leakage, and particularly fuel tank leakage, is always a problem sometime during the life of an aircraft. The problem typically becomes amplified as the aircraft ages, particularly near the end of its life. Excessive component wear, in general, is also reported to be a problem.
- f. Environmental Control System (ECS) - ECS problems tend to vary. Problems have been noted relative to bleed air overheat detectors, air cycle machines, temperature controls, pressurization, and bleed air ducts.

Periodically the question arises as to whether corrosion is a problem for subsystems. As indicated above, corrosion does not appear to be a widespread problem except for Landing Gear. Numerous corrosion problems have been noted with side braces, trunions and torque arms. The only other corrosion problems noted involved the rod end of a specific elevator actuator, the rain duct on another aircraft and several isolated cases of electrical connectors.

Even though subsystems are one of the largest contributors to unscheduled maintenance, System Program Offices previously tended not to perform pre-emptive maintenance unless the failures potentially impacted safety of flight. However some programs have started to change this philosophy. When queried on plans to correct poor performers, several System Program Offices reported planned actions involving the replacement of flight control actuators, stripping and resealing of fuel tanks, and replacing aircraft wiring. Likewise, six System Program Offices identified plans for subsystem upgrades, overhauls or modifications.

PROGRAMMATIC ISSUES

In reviewing the issues associated with each of the System Program Offices, two categories of subsystem issues were noted - programmatic issues and technical issues. The basic programmatic issues focused on inadequate funding, inaccurate databases for tracking unscheduled maintenance actions, lack of serialized part number tracking for mechanical system components, and failure to implement the Integrity Programs as a disciplined engineering process for sustainment. Below is a more detailed discussion of each issue:

- a. Inadequate funding. Funding for aging aircraft research and development is probably the number one problem faced by the program managers. Funding of aging aircraft requirements for subsystems is even more challenging because the subsystem problems normally are not classified as immediate safety issues. Instead, the failures affect aircraft availability. Justification can be difficult for non-safety related problems because the available funding is normally consumed by the safety related problems. When funding does become available, it may be impossible to support all the necessary areas. Thus there is a need to establish priorities.
- b. Inaccurate databases for tracking unscheduled maintenance actions. The most discussed issue during these reviews involved the need for an accurate component reliability and maintenance data tracking system. Such a database is truly the starting point in identifying the "bad actors" so that we can determine where best to direct our maintenance efforts and dollars. System Program Office that discussed component tracking indicated a concern with the current Reliability and Maintainability Information System (REMIS). The offices that seriously tracked the reliability and maintenance of their components stated that they would start with the REMIS database but would confirm the reliability of the data through detailed discussions with the maintainer. Frequently the maintainer could not confirm the failure rates or would identify new problem areas. Since the database is only as good as the data entered, tracking systems must be established that are more user friendly, and facilitate quick and accurate entry of the data. Attention must be given to making accurate inputs as foolproof as possible. Also a sufficiently complete set of component or part identifiers must be included in the database so that a failure or maintenance action can be accurately attributed to the correct part. For example, the Air Force Reliability and Maintainability Information System does not have part identifiers for wiring. Thus a wiring failure frequently gets erroneously entered against the electrical component it powers.
- c. Lack of serialized part number tracking. Another need in establishing a proactive sustainment program is the existence of a serialized component tracking system. For example, one program office emphasized that the landing gear is not maintained as a matched set - i.e. parts are frequently mixed and matched during field maintenance. When such a gear is returned for overhaul, the depot has no idea of the condition or time accumulated on the various parts within the gear. Likewise, when a given part is overhauled, it is returned to stock. That part will then be used on the same type of aircraft (e.g. a C-5) or, in some cases, a totally different type of aircraft (e.g. F-15). A hydraulic accumulator is a prime example of a component that may be overhauled and returned to use on a totally different platform. Over time, the accumulator may encounter numerous overhauls with the structural fatigue life of the cylinder being exceeded. With no type of serialized tracking, the user has no indication when a specific unit has exceeded its design life. With today's availability of computers and computer technology, there are numerous possibilities for serialized tracking. Bar codes can be embedded on each component nameplate and scanned into a central tracking system upon installation and removal. Chips can be embedded into a component that records

operating times from an existing onboard computer. More detailed life related parameters can be calculated and either stored on a component computer chip or saved on a central aircraft computer and subsequently downloaded to a centralized ground data tracking system. This is similar in concept to the Individual Aircraft Tracking Program integral to the Aircraft Structural Integrity Program.

- d. Failure to implement the Integrity Programs. As previously noted, the Aircraft Structural Integrity Program, ASIP, has been a very effective tool in maintaining our aging fleet. It was initiated in the late 1950's and is used for both development and sustainment. As a result, the Mechanical Equipment and Subsystems Integrity Program, MECSIP, was developed in the 1980's and patterned after the highly successful ASIP. The program offices have been slow in implementing the Integrity Program to subsystems, but we are now beginning to see some of the System Program Offices implement MECSIP as the disciplined engineering process for sustainment. As with ASIP, what MECSIP offers the System Program Offices is a proactive process that allows one to understand where the problems reside so that we can better focus our maintenance actions and dollars to improve aircraft safety, suitability and effectiveness. Consequently it is essential that our program managers understand the benefits of MECSIP and implement the disciplined engineering process into their weapon system programs.

TECHNICAL ISSUES

There were also several technical issues identified for subsystems throughout the survey. Specific needs noted include:

- a. Capability to predict remaining life of components. As indicated previously, there has been a tendency to fly the subsystems to failure. Two of the driving reasons are (1) we have no method to determine remaining component life and (2) there is no component level serialized tracking system. However the need does exist to establish some method to predict remaining life so that we can plan the necessary maintenance actions to improve aircraft availability and reduce maintenance cost. One potential technique for electrically driven components would be to develop a correlation between electrical signature (e.g. current draw) and component wear. Some work has been done in this area with promising results. There may also be other techniques that could be developed with similar results.
- b. Non-intrusive techniques to assess wiring health. Degradation of wiring insulation, coupled with wire chafing, is a problem noted on many of our aging aircraft. This creates not only a significant maintenance burden but also a potential safety issue should flammable fluids or explosive vapors be present. Attention is beginning to be focused on developing techniques to determine the integrity of wiring system. However, we must emphasize the need to develop quick, simple, non-intrusive methods that can pinpoint low-level shorts associated with a specific wire.
- c. Non-intrusive techniques to assess condition of mechanical cables. Cable wear associated with flight controls, engine throttle, etc. is a significant problem with many of our older non-fly-by-wire aircraft. Unfortunately, the condition of the cable can frequently be determined only through removal of the cable. Several program offices noted a need for developing a non-intrusive method for assessing the health of installed cables.
- d. Machine to measure tube configuration data. Tube failure is always an issue with our aging aircraft. When the tubing fails due to chafing, fatigue, etc., the new tubing is frequently

fabricated at the base level. However, the tube bend data is not always available or the data does not always result in a newly fabricated tube exactly the same as the tube being replaced. Incorrectly configured tubing can result in tube pre-loading that, in turn, can result in premature failures. Since many of the fluids (e.g. hydraulic and fuel) contained within the tubing are flammable, tube failure can be a potential safety of flight concern. Consequently a need has been identified for a machine that can accurately measure the configuration of a tube that was just removed and convert it to set of data necessary for subsequent tube fabrication.

CONCLUSIONS

In the past, the USAF has tended to take an approach for subsystems whereby we would fly the systems to failure – i.e. little or no forced maintenance planning was done relative to subsystems. This was feasible because we seldom loose aircraft due to subsystem type of failures since our basic design philosophy is to provide sufficient subsystem redundancy to preclude the loss of aircraft. However, the USAF has now begun to recognize the impact of subsystems on aircraft availability and downtime. Consequently several specific actions have been initiated:

- a. The Air Mobility Command has initiated an Aging Aircraft Process Action Team to address the issues associated with their aging fleet.
- b. The Aging Aircraft System Program Office now includes air vehicle subsystems in their yearly surveys of over thirty aircraft systems.
- c. The results of the surveys are being communicated to government and industry organizations responsible for research and development.
- d. The Air Mobility Command is adopting the Mechanical Equipment and Subsystem Integrity Program as a method for providing a disciplined engineering process to the sustainment of their weapon systems.

Even though the Air Mobility Command is still in the early stages of implementing the integrity program for subsystems, it is an initial and necessary step towards characterizing the problems that require further research and development.

With an initial understanding of the current problem areas, we now have a starting point for identifying where best to invest our research and development efforts. Similar to what Lincoln indicated [9], many of these same aging military aircraft problems have similar or exact parallelism in the aging commercial aircraft world. It is therefore prudent that these problems be worked through the combined talents and resources of both the military and commercial worlds so that we can more effectively channel the limited research and development dollars in the most efficient manner possible.

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